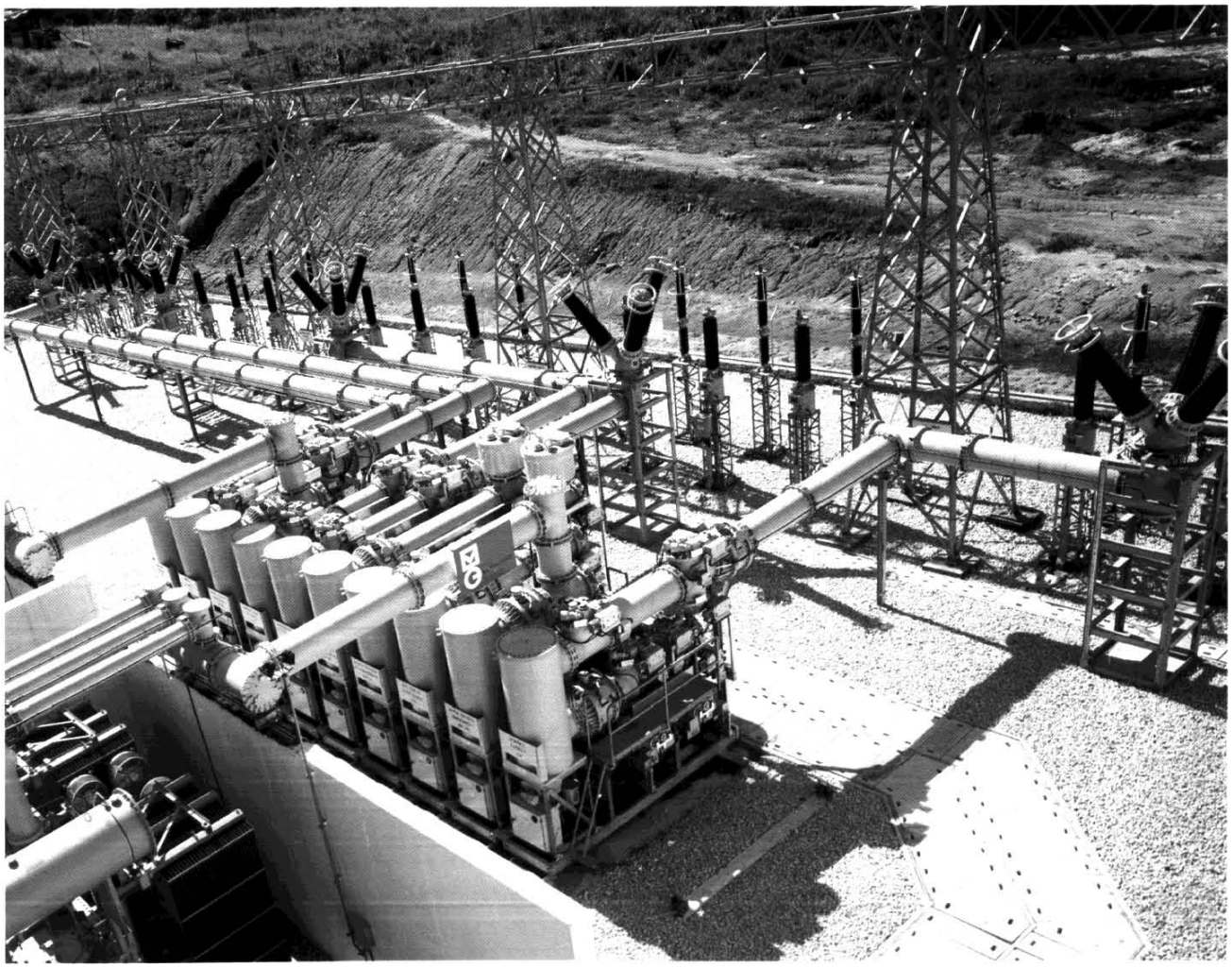
HV Transmission SF6 gas insulated switchgear

Hexabloc TH7 72.5 to 170 kV



MERLIN GERIN

mastering electrical power

GROUPE SCHNEIDER

summary

introduction

The increasing demand for electrical energy in big cities and industrial areas has made it necessary to bring EHV systems right to the doorstep of load centres.
This has led Merlin Gerin towards the development of a range of SF6 gas insulated HEXABLOC switchgear.
Thanks to the choice of technical options and the technology used, Hexabloc achieves the following objectives :
- high safety
- very high reliability
- insensitivity to pollution
- compact size
- outdoor or indoor installation
- ease of transport, installation and operation
- reduced maintenance.

Based on its experience and aiming at improving operating conditions in increasingly smaller substations, Merlin Gerin has designed the Hexabloc TH7 in which the three phases are contained within a single metal encapsulation. Hexabloc TH7 covers voltages from 60 kV to 170 kV.

It ensures :

High safety

With gas insulated switchgear (GIS) all foreign bodies (persons, animals, tools) are prevented from coming into contact with live parts. This ensures maximum safety to personnel and increased continuity of operation. The equipment is designed for internal insulation coordination in such a way that it provides a wider safety margin between phases than to earth. Moreover, the burn-through time for enclosures in the very rare cases of internal faults is increased with the three-phase technique.

Very high reliability

The equipment is designed to ensure reliability of operation.
For example :
- the support insulator design gives it remarkable properties from the dielectric, thermal, mechanical and pressure withstand point of view.
- the busbars are flush-mounted and bolted at one extremity in order to improve their resistance to electrodynamic withstand.

Using a single enclosure for the three phases reduces the risk of SF6 leaks.

Insensitivity to pollution

All live parts are totally protected from atmospheric pollution (fog, salt, sand,...) or industrial pollution (dust, smoke, gas,...).

Large reduction in size

Large power consumption areas, i.e. towns or major industries, are usually where space is precious and where space saving is an important factor in lowering the cost.
Using SF6 gas as a dielectric medium reduces insulation distances. For a given layout, GIS is much more compact than the conventional «open» type.
Three-phase design underlines the advantage of GIS : the centre to centre distance of two adjoining three-phase bays is 1.3 metres. The relation between the surface areas of the three types of construction can be expressed as follows :
- Conventional substation : 100
- Single phase Hexabloc : 10 to 15
- Three-phase Hexabloc : 5 to 7

Installation : indoor or outdoor

Hexabloc has been designed for outdoor unprotected installation. The reduced size allows the equipment to be installed in enclosed premises which can also be small, therefore less costly.

Elimination of harmful effects

Harmful effects caused by the corona and radio interferences are totally eliminated with GIS.
Moreover, the Hexabloc substation is silent. So there is no noise problem when installed in residential areas.

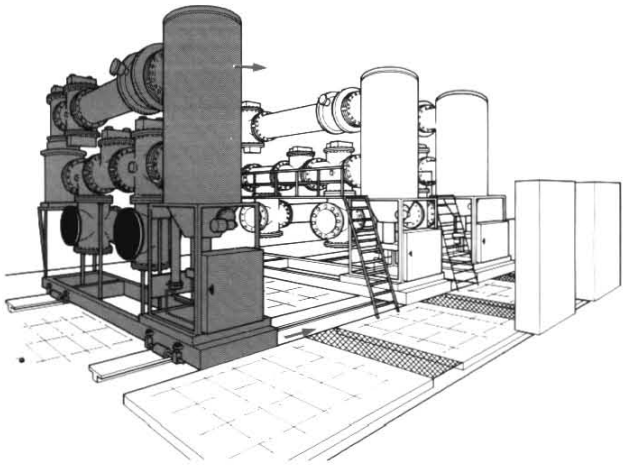
Ease of transport and installation

A Hexabloc TH7 substation consists of factory assembled and tested bays transported as such to the site. Each bay is placed on the civil works without any additional assembly other than connections between the various bays, and to incoming and outgoing feeders.
Bursbars are fitted with connectors consisting of robust contact fingers.
The low voltage control and monitoring circuits are prewired.
The earthing circuit is fitted in the works.
Civil works are kept to a minimum with two rails or concrete beams and power cable ducts.

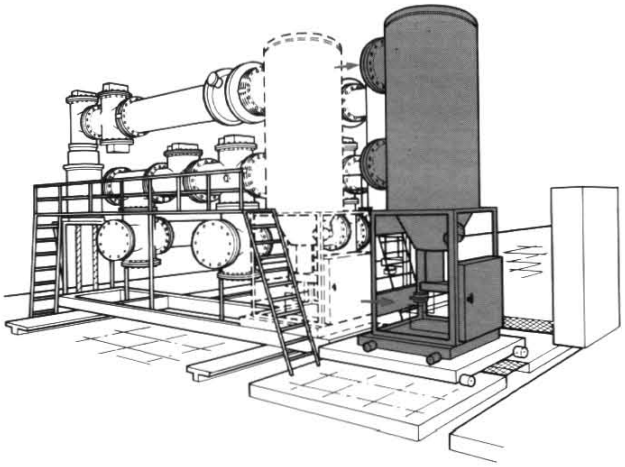
Simplified maintenance and easy operation

Merlin Gerin's objective was :
- to simplify maintenance
  - □ mechanical protection provided by the enclosures
  - □ chemical neutrality of SF6
  - □ electrical endurance of the circuit-breaker
  - □ better overall view of the single line diagram, thanks to the three-phase design.
- to provide sufficient room for the necessary operations, whilst gaining the benefit of a compact design
  - □ access to operating mechanisms provided by fixed gangways between bays
  - □ circuit-breakers removable on rails after disconnection without opening the enclosure
  - □ standardization of sections requiring only a small number of spares to be kept in stock.
  - □ dismantling points provided for long busbars.
  - □ easy removal of gas barrier insulators (see equipment description).
  - □ reduced weight due to light alloy construction, small dimensions, etc...
  - □ disconnector position indicator directly linked to the moving contacts.
- to ensure continuity of service by keeping at least one busbar live in the case of multiple busbar substations.

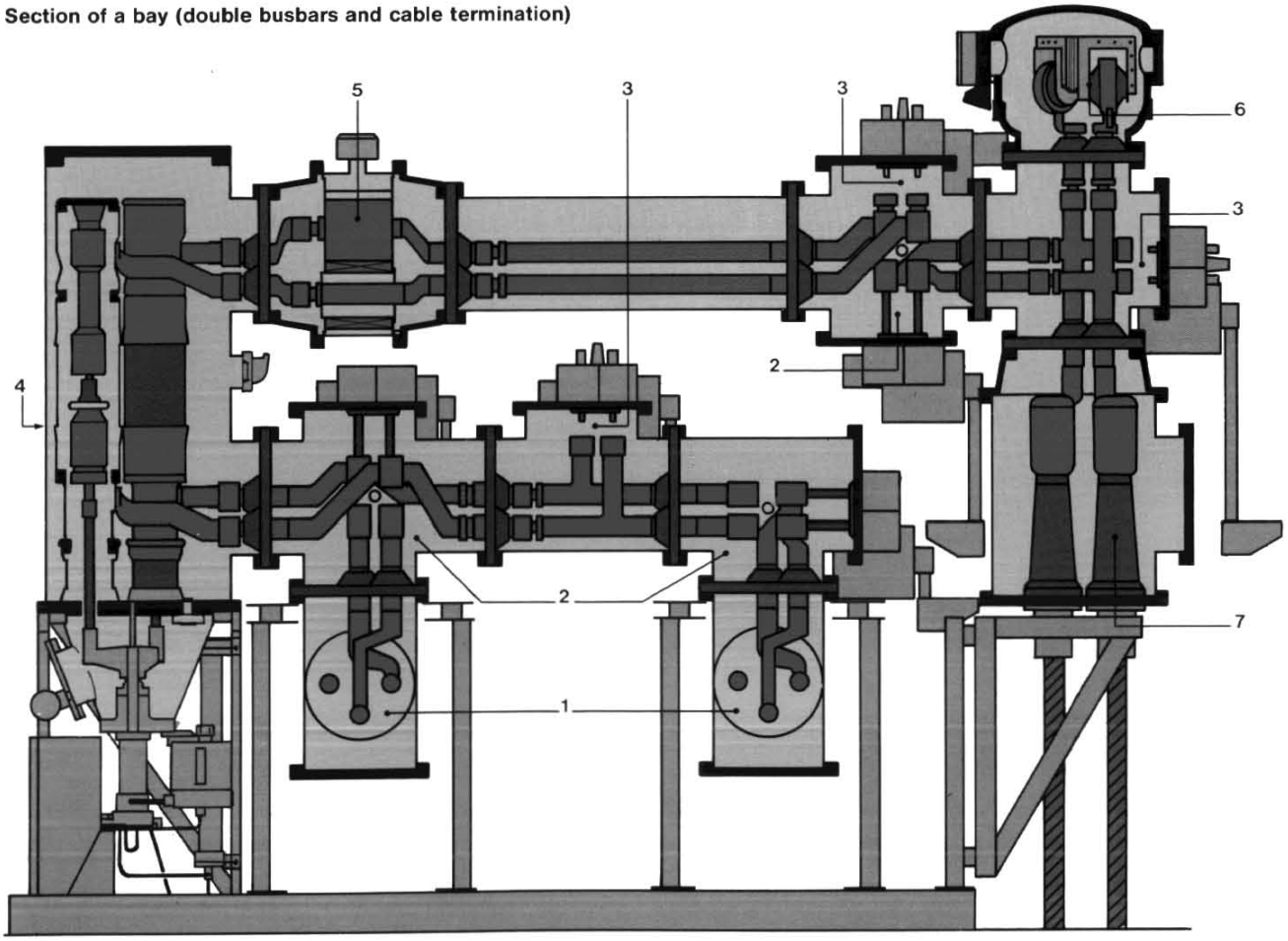
Installation
the fully factory assembled bay is installed by sliding on supporting rails



Handling of circuit breaker
after disconnection, the circuit breaker can be removed and carried on rollers



Section of a bay (double busbars and cable termination)



1 Busbars
2 Disconnector
3 Grounding switch
4 Circuit breaker
5 Current transformer
6 Voltage transformer
7 Cable termination

technical options

The major technical options distinguishing Hexabloc TH7 equipment are :
- Metalcladding for the three-phases by a common enclosure
- Insulation
- Internal compartments.

Metalcladding
The cylindrical metal enclosures used for GIS are electrically and mechanically connected in order to :
- ensure a sealed enclosure
- protect the switchgear
- form an earthing circuit.

Insulation using SF6 gas
SF6 has been chosen because of its excellent dielectric and interrupting properties.

Internal compartments
These ensure internal separation of functions. Each piece of equipment forms a separate sealed compartment which limits any internal faults or SF6 leaks to a single compartment.

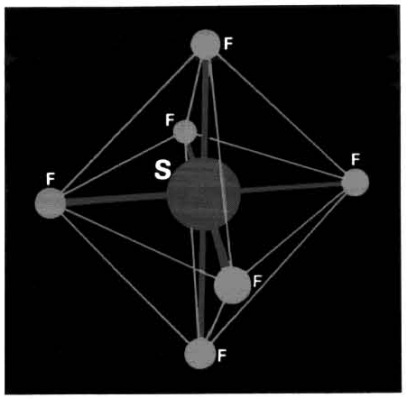
Separate compartments simplify maintenance :
- finding leaks is easier
- replacing a given piece of equipment is simplified as it is an independent element which can be depressurized without affecting continuity of service of adjacent bays.
- limiting the portion of work reduces the quantity of gas to be handled thus reducing down-time.

Other features of separate compartments are :
- pressure monitoring, fault location, fault limiting. If the pressure of SF6 gas accidentally drops to the atmospheric pressure, rated voltage withstand is still guaranteed.

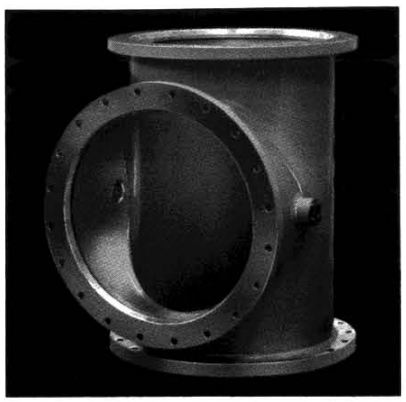
However, overvoltage withstand and breaking capacity are directly linked to the pressure of the gas.

The pressure is therefore permanently monitored in each compartment by a temperature-compensated multilevel setting plug-in type pressure-switch. Moreover, even though the Hexabloc design reduces the possibility of an internal fault to a minimum, each compartment is fitted with an overpressure limiting device. This is a disc (or «membrane») designed to function under pressure, like a safety valve.

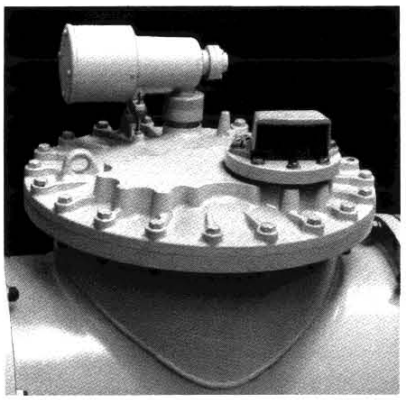
SF6 molecule



Enclosure

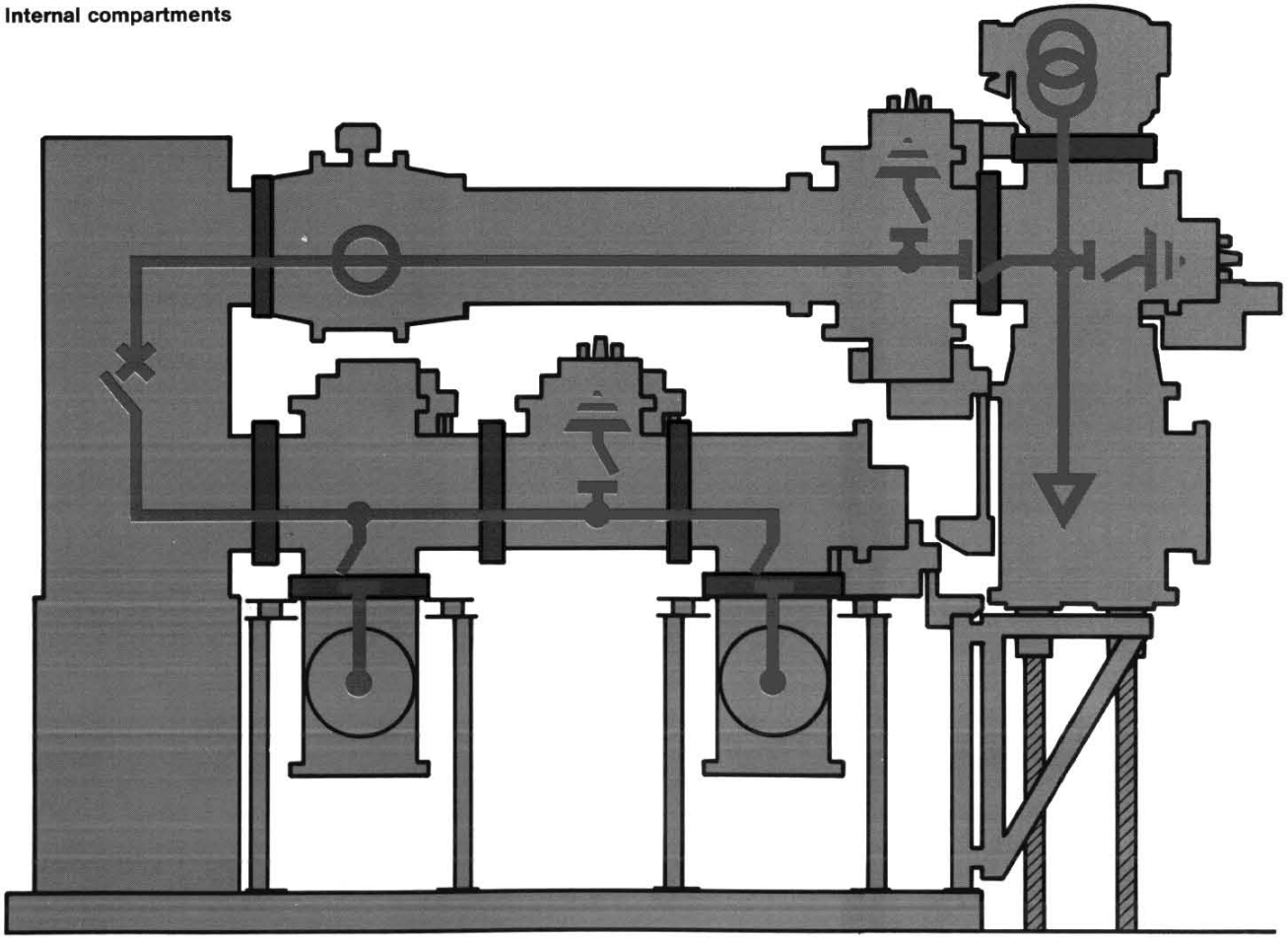


Enclosure cover



Enclosure cover equipped with safety accessories : pressure switch and overpressure limiting device

Internal compartments



technology

Hexabloc technology is based on many years'experience :

■ **the metal enclosure** is made from a light aluminium alloy. This has several advantages :

□ reduction in weight - easy handling
□ resistance to corrosion
□ no eddy currents, thus reducing overheating.

■ **tightness**

The tightness of enclosures is obtained with well-tried manufacturing processes :

□ units positioned with tools before welding
□ automatic welding
□ checking tightness of welds.

Tightness of sub-assemblies is achieved :

□ between compartments, with insulators which also act as conductor supports.
□ between compartments and outside, with o-rings : one or two concentric rings depending on their position and size.

■ **absorption of SF6 decomposed products.**

This is achieved by absorbants placed in compartments where an electrical arc would be produced (e.g. circuit-breaker compartment).

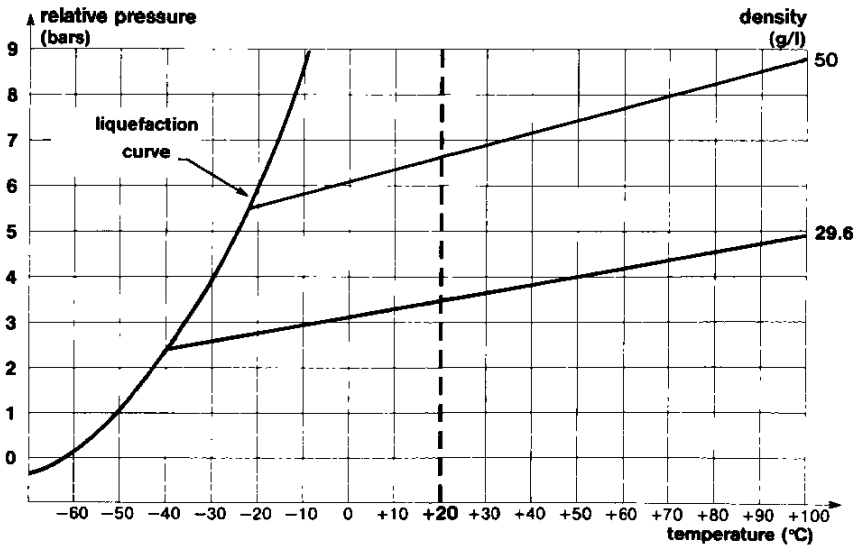
■ **particle trap**

All the compartments are provided with particle traps located on the gas barriers.

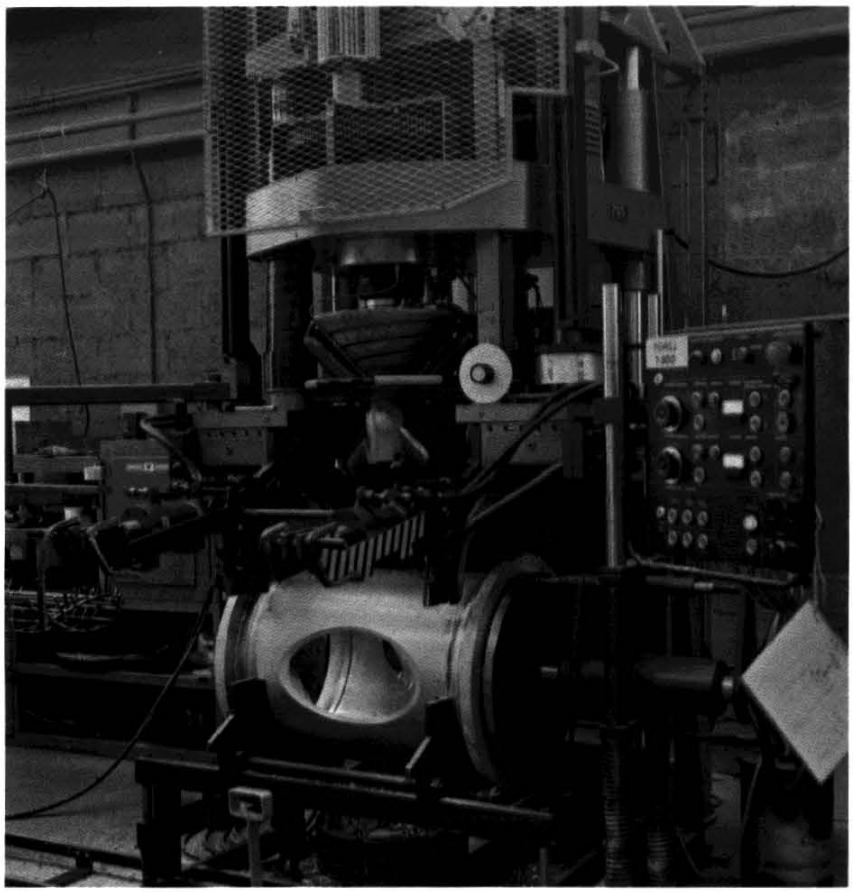
■ **choice of SF6 pressure**

SF6 pressure, monitored by the pressure-switches has been fixed at 3.8 bars (relative pressure) at 20°C for all the compartments except the breaker compartment which is at 6.5 bars.

SF6 pressure variation versus temperature



Machine for forming of tee-connections



Tightness device

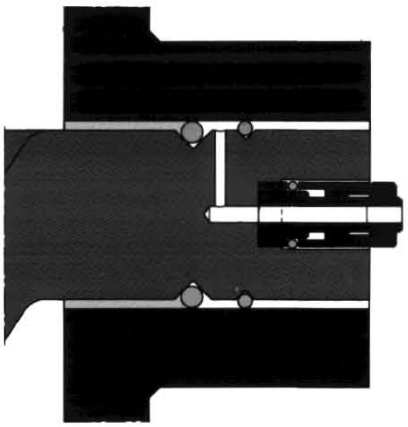


Diagram of a connecting flange with its two o-rings. The venting aperture is for the checking of the inner seal gastightness.

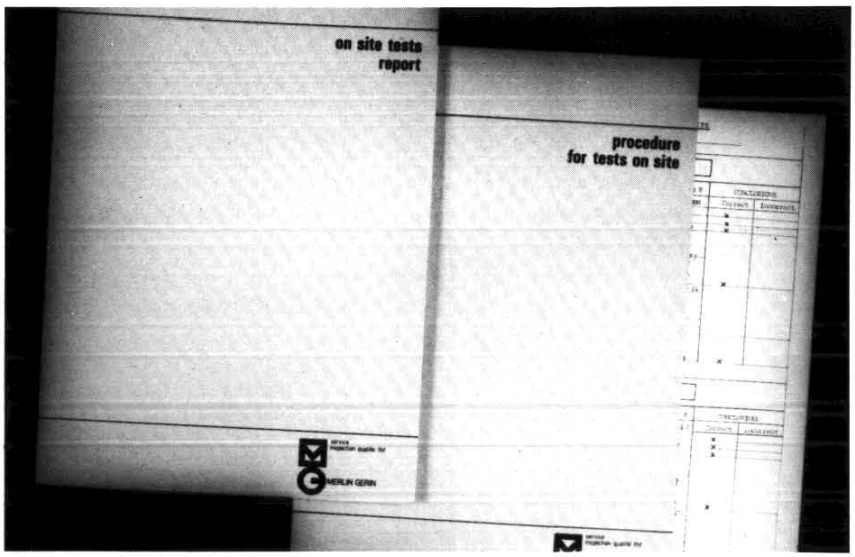
Automatic machining system with digital control

quality

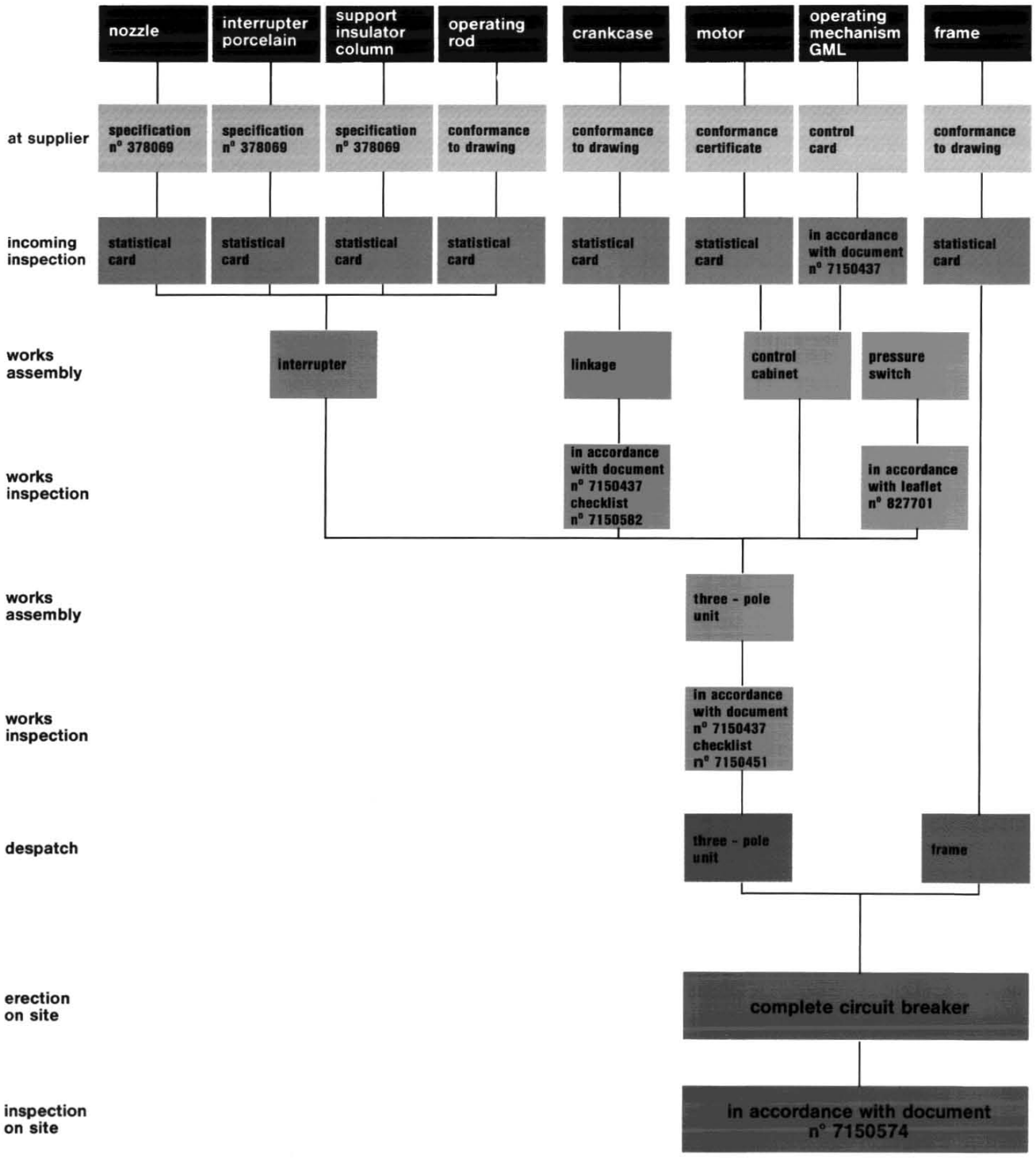
The products'ability to perform to the customer's satisfaction is Merlin Gerin's basic objective.
To achieve this objective, Merlin Gerin has a Quality Organization based on the concept of Quality Assurance, that is a network of planned, systematic means designed to ensure conformity of supplied products and services with the client's requirements. This system prevents, detects and corrects any possible malfunctioning, and also avoids its recurrence and ensures that the correcting actions are implemented:

- the quality assurance programme is in charge of the implementation of the Quality Assurance programme whose procedures for organization and internal operations are documented in the regularly updated Quality Assurance Manual. This manual satisfies the requirements of the Quality Assurance standard reference ISO 9001.
- the Product Quality Assurance is responsible, broadly speaking, for the control of the product design and its application to various contracts, the supplier's audits and the schedules for inspection visits and test planning.
- the Quality Inspection is performed through out the manufacturing processes. It is a valuable «tool» for the Quality Assurance.
- the Incoming Quality Inspection ensures the quality control of the total external procurement.
- the in Process Quality Inspection ensures the control of intermediary operations of assembly, final electric and mechanical tests and checks conformity of products with the requirements specified in the contract.
- the Final (on site) Quality Inspection ensures the controls of the proper on-site assembly operations as well as the dielectric tests prior to commissioning. All results obtained during inspection visits and on-site tests are documented in a test report handed over to the customer.

To sum up, Merlin Gerin places great emphasis on the Quality Assurance and Quality Control and, for these reasons, stringent quality control measures are imposed along the manufacturing and assembly of the product.



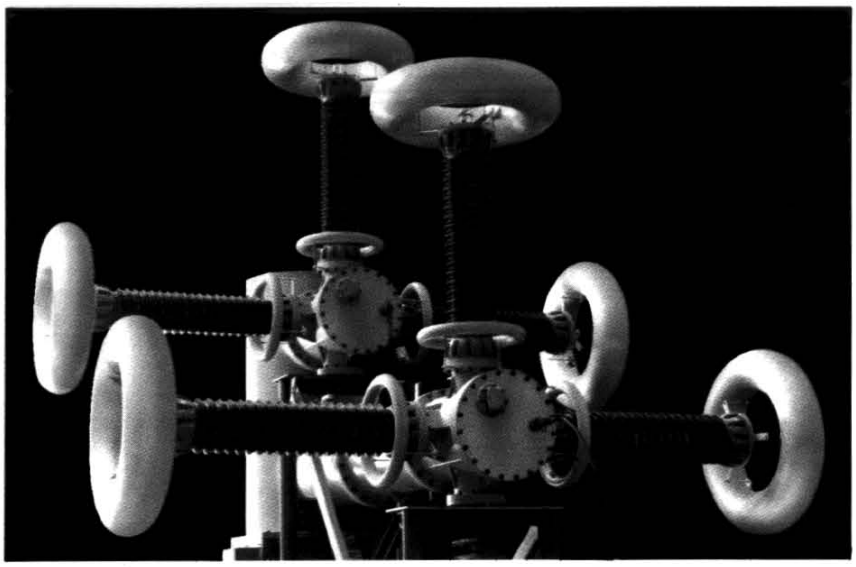
Quality Inspection : circuit breaker control «flow chart»



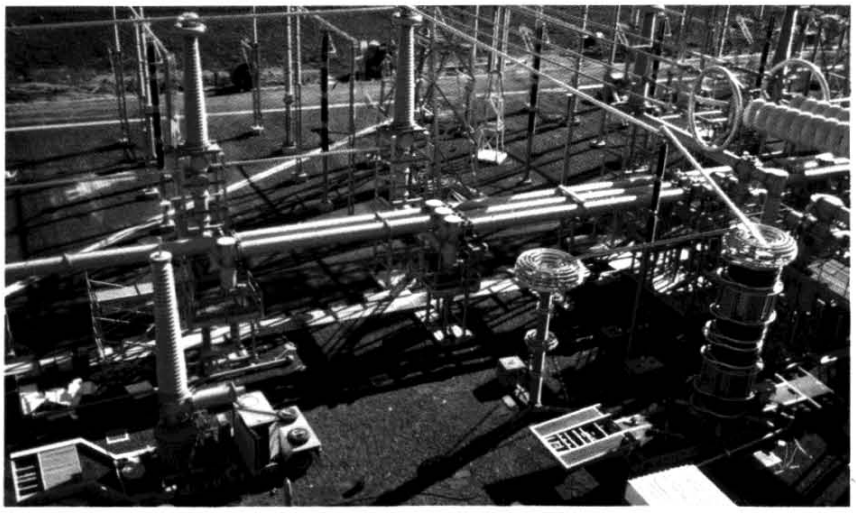
tests

Type tests
Hexabloc TH7 has undergone type tests prescribed by international standards and the specifications :
- dielectric withstand
- temperature rise
- short circuit withstand
- breaking capacity tests (terminal and short line faults, etc..)
- internal faults
- measuring contact resistances and operating speeds
- mechanical and environmental tests
- long-time ageing tests.

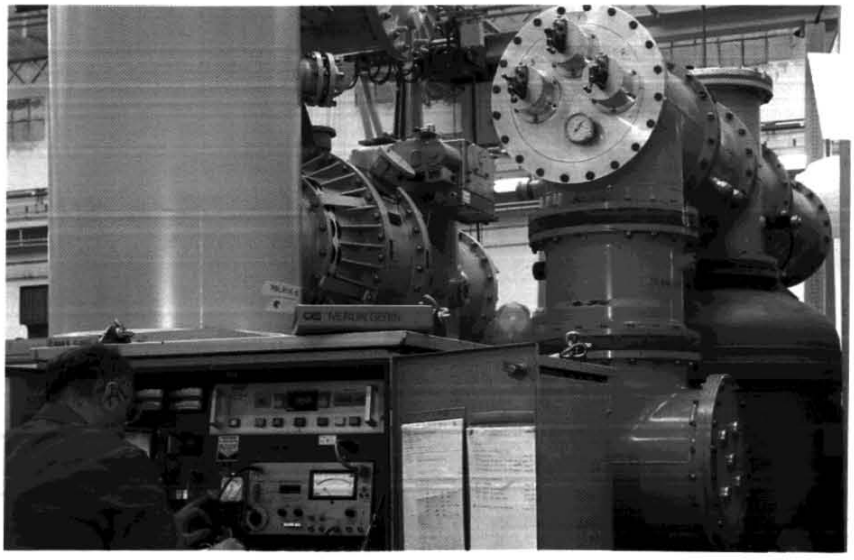
Routine tests
- in the works : tightness, dielectric including partial discharges, contact resistance and operation tests.
- on site after erection : tightness of sub-assemblies, dielectric, contact resistance and operating tests.



Dielectric tests on TH7 units



Dielectric tests on site, after erection



Dielectric routine tests using a gas insulated test unit

Hexabloc TH7 electrical characteristics and functions

electrical characteristics

Rated voltage(kV)	170
Rated insulation level (kV peak)	750
Rated current (A)	
■ busbars	3150
■ switchgear	3150
Circuit-breaker breaking capacity from 50 to 60 Hz (kA)	40
Short time current withstand (kA/3s)	40

insulation

The switchgear is insulated by :
■ the SF6 gas
■ support insulators whose material (epoxy resin) and shape have been determined by computer studies and numerous tests in order to provide the switchgear with :
□ mechanical resistance to permanent and electrodynamic withstand
□ dielectric withstand (power frequency, lightning and switching impulse, low partial discharges, atmospheric pressure withstand)
□ thermal withstand
□ overpressure withstand.

functions

Thanks to the building block feature whatever the layout, from the simplest to the most complex, the Hexabloc TH7 provides the design engineer with all the elementary functions to build a substation :
■ circuit-breaker
■ disconnector
■ grounding switch
■ instrument transformers (CT and VT)
■ busbars, links, duplicate busbar common points
■ interfaces with overhead line and with power transformer
■ control cabinet, etc...

DTH7 circuit-breaker

Interrupter
The DTH7 is a SF6 single pressure puffer type breaker.
The «current flow» function and «breaking function» are separate and entrusted to different contacts of the same moving unit :
■ «main contact» for current flow
■ «arcing contact» for breaking

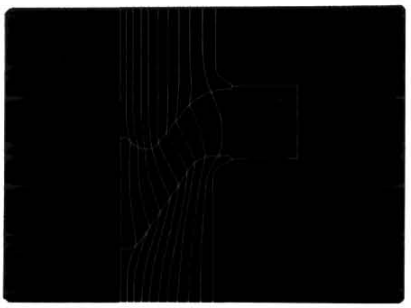
1 closed circuit-breaker
□ the main contact is closed
□ the arcing contact is closed
□ the compression cylinder is filled with gas at the rated pressure.

2 opening circuit-breaker
The moving unit moves back, actuated by the insulating rod. This induces :
□ the opening of the main contact the current is then totally shunted onto the arcing contact.
□ the moving compression cylinder to move back and the SF6 to be compressed in the cylinder.
□ after a short-time lapse, the arcing contact to open. The arc is forcibly cooled by the SF6 from the cylinder. An insulating nozzle provides the optimum arc blasting conditions.
Interruption arises from :
□ arc cooling
□ regeneration of the dielectric medium after current zero.

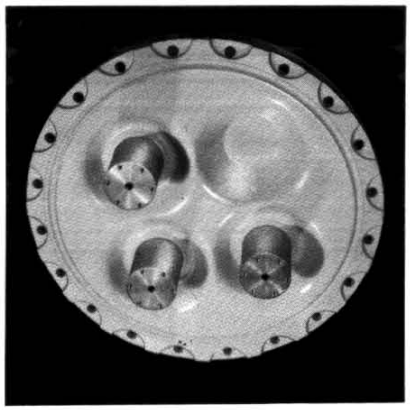
3 open circuit-breaker :
□ the main contact and arcing contact are open and ensure voltage withstand.
□ the compression cylinder is ready to be filled at the next closing operation through the movement of its check valve.

A single vertical cylindrical enclosure houses the three circuit-breaker poles. It is fitted with incoming and outgoing insulators which support the three-pole connection links. The insulators are arranged in such a way that all connections are possible using the minimum space.
The enclosure is placed on a wheelmounted supporting structure which houses :
□ the hydraulic operating elements (differential hydraulic jack, valve, etc...)
□ the control cabinet.
The identical poles are each equipped with an interrupter. Each interrupter is surrounded by an insulating enclosure which prevents the propagation of ionized gasses from one pole to another. Inside this enclosure, an absorbant collects and neutralizes SF6 decomposition products.
Each pole is linked to the incoming and outgoing busbars by light, rigid, cast alloy connections.

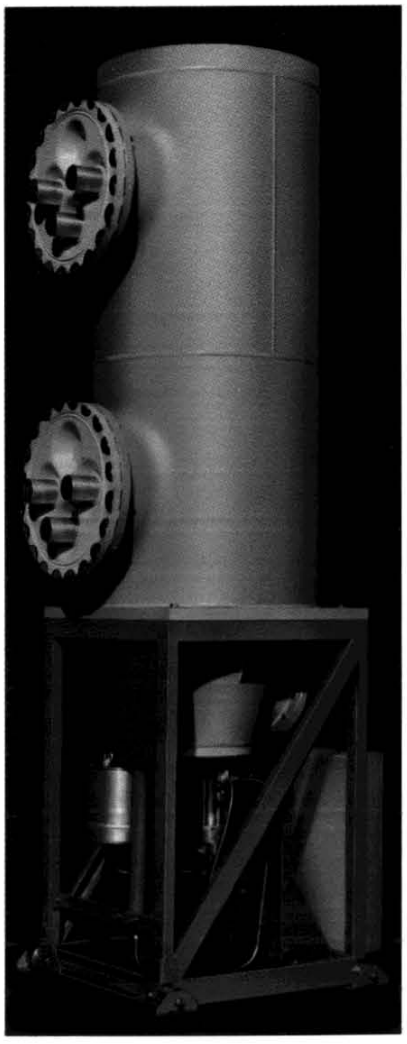
«Computer aided design» :
predetermination of electrical field distribution in an insulator



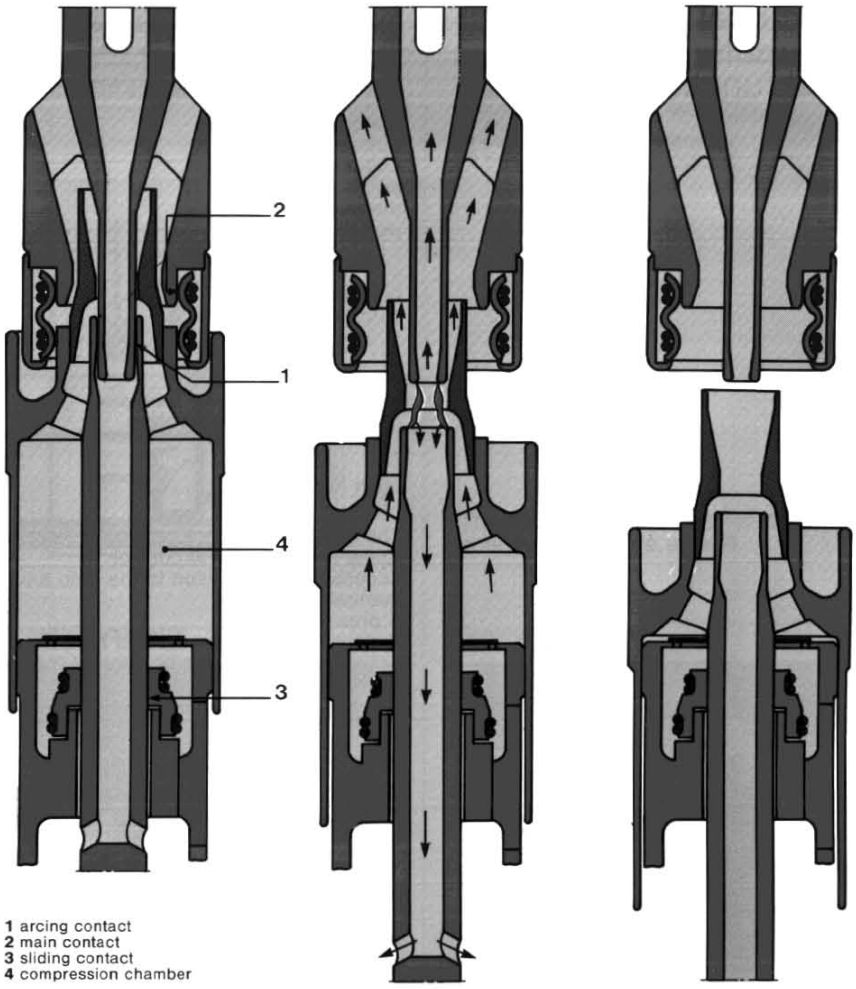
Support insulator



Circuit breaker



Circuit breaker interrupter



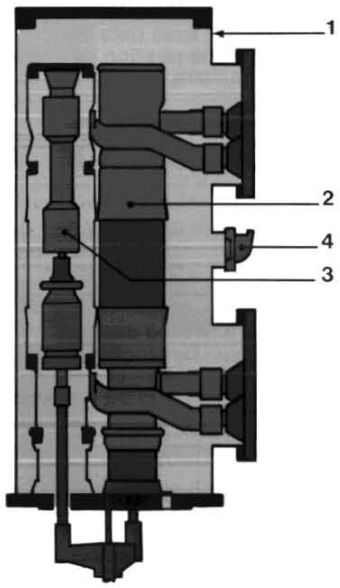
1 arcing contact
2 main contact
3 sliding contact
4 compression chamber

in «closed» position

during tripping operation

in «open» position

Circuit breaker. Section of live part



1 Enclosure
2 Pole
3 Interrupter
4 Overpressure limiting device

Hexabloc TH7 electrical characteristics and functions

Operating mechanism
The moving contact of each pole is linked by an insulating rod to a triangular link, actuated by the hydraulic jack.
The hydraulic jack is fed as follows :

low pressure
auto-start
motor pump
or
manual stand-by
pump
↓
nitrogen filled
accumulator
↓
open/close operation of
main hydraulic valve
controlled by electro-valves
↓
main hydraulic jack

The hydraulic cabinet located in the frame houses several control accessories in addition to the auto and manual pumps, i.e. :
□ pressure-switch
□ auxiliary contacts actuated by an actuator repeating the position of the main hydraulic jack
□ safety valve.

disconnector

The three pole disconnector enables the design of the most varied layouts using a minimum number of compartments.

There are two basic alternatives available :
■ line disconnector (incomer and feeder on same axis)
■ right angled disconnector (incomer and feeder perpendicular).
The disconnector position is displayed by a moving part, directly fixed to the contact support visible through a transparent housing fixed onto the crank-case. Thus, the position indicator is fully reliable as there is no intermediate coupling.
Moreover, inspection windows are provided to check the contact positions inside the enclosure.
The crank-case itself holds the single mechanical device which transmits the operating mechanism movement to the contact holder.

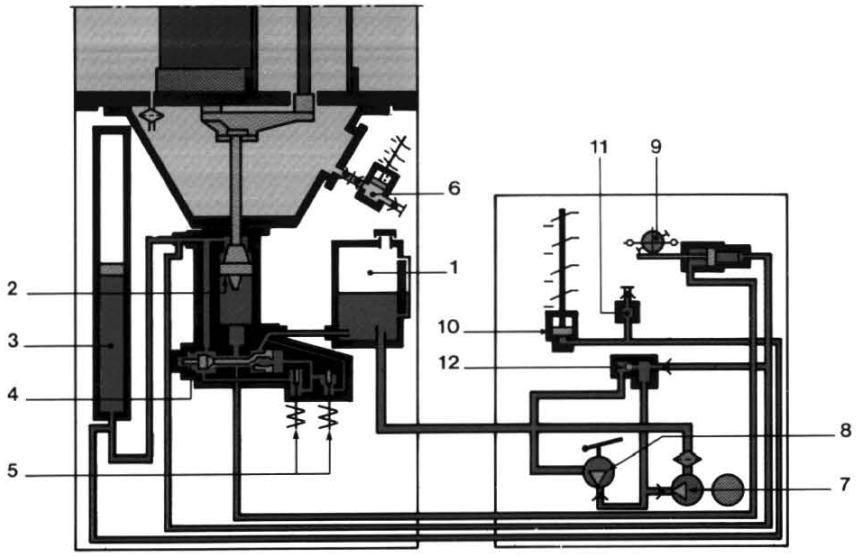
It is also equipped with :
■ an SF6 pressure-switch
■ an overpressure limiting device.
The mechanism can be blocked in the «open» or «closed» position if the electric operating unit is to be removed.

grounding switch

The grounding switch operates along the same lines as the disconnector.
Under normal conditions, the contacts are linked to the earthing circuit via bushings fitted on the crank-case. For special measurements,namely current injection, contact resistance, etc..., each outlet can be separately insulated from the earthing circuit.
Contact is made through three studs solidly fixed to the live parts which are to be grounded.
Its operating mechanism is identical to that of the disconnector. It can also be of the quick-make type because of the high speed stored energy system. In this case, the grounding switch has a full fault making capacity.
It also has (with electrical operating mechanism) a breaking capacity sufficiently high to interrupt inductive or capacitive currents.

All combinations are possible betwee
■ manual/electrical operation
■ quick/slow make

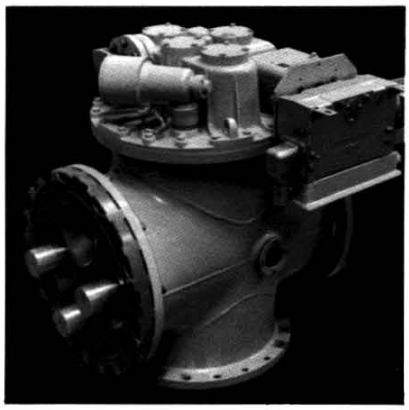
Circuit breaker hydraulic operating mechanism



1 Oil tank
2 Jack
3 Pressure accumulator
4 Main valve
5 Close and trip coils
6 SF6 pressure switch
7 Motor pump
8 Hand pump
9 Auxiliary contact control device
10 Oil pressure switch
11 Connection for calibrated gauge
12 Safety valve

The breakers can be supplied for single-pole auto-reclosure as well.

Disconnector

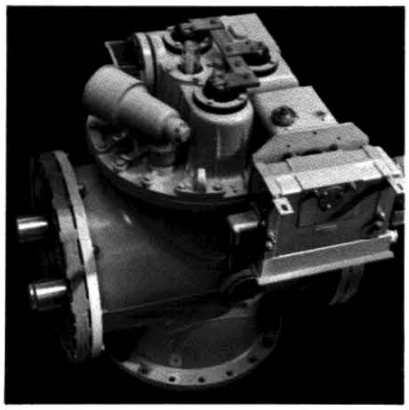


Position indicator

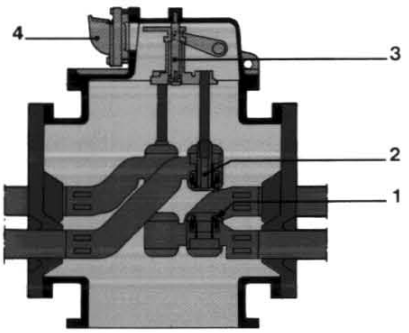
in «closed» position

in «open» position

Grounding switch

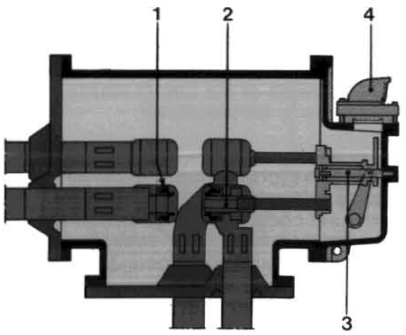


Disconnector - Section



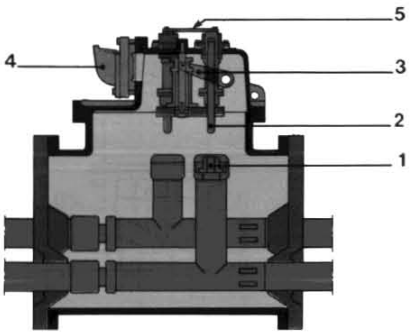
Line disconnector

1 Fixed contact
2 Moving contact
3 Operating mechanism
4 Overpressure limiting device



Right angled disconnector

Grounding switch. Section



1 Fixed contact
2 Moving contact
3 Operating mechanism
4 Overpressure limiting device
5 Earth circuit connection

Hexabloc TH7 electrical characteristics and functions

operating mechanisms

The disconnector and grounding switch operating mechanisms are of the same type.
They can be manual or electrical.
In both cases, they can have interlocks with either locks, padlocks or electrical interlocks.

Operation :
■ **manual** : with a linkage and operating lever.
■ **VEGALEC electrical operating mechanism**
This is the reduction gear motor, worm screw type. The nut on the worm screw drives a handle on the disconnector or grounding switch mechanism axle.
At the end of its stroke, the nut is disengaged to avoid high stresses. Nevertheless, the mechanism remains blocked in the position it has reached (open or closed).
Electrical operation is always backed up by manual stand-by control (or removable rod). Its use blocks the electrical operation.
The auxiliary contacts are fitted directly on the end of the control rod. Manual or stand-by manual operation is accessible from the access gangways of each bay.

voltage transformer

The V.T. is electromagnetic, three-phase SF6 insulated.

The cylindrical enclosure houses :
■ the magnetic circuit
■ HV windings linked to the phase conductors which enter the enclosure via the insulator.
The insulator closes the enclosure.
■ LV windings connected to terminals in a terminal box, outside the enclosure.
■ an electric field distributor screen.
The enclosure is fitted with :
□ a gas refilling device
□ a pressure-switch
□ an overpressure limiting device.

current transformer

The C.T. is of the three-phase, ring core type, with one or more cores. The cylindrical enclosure is placed between two elements of the circuit whose current is to be measured.

It houses :
■ the three-phase conductors, which act as primaries
■ the secondary windings which are separately mounted for easy interchangeability and connected to one or three terminal boxes outside the enclosure. A secondary voltage limiting device can also be provided in case the circuit opens inadvertently.
■ the electric field distribution screen.
It is fitted with :
□ a gas refilling device
□ a pressure-switch
□ an overpressure limiting device.

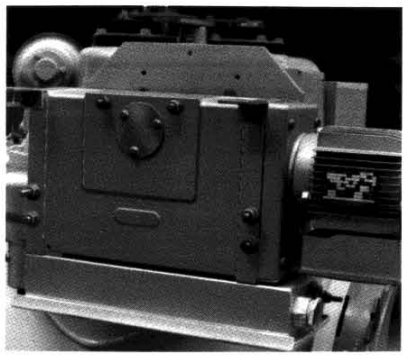
surge arrester

Various types of surge arresters can be installed in SF6 enclosures (especially gapless zinc oxide type).
This system allows direct connection between the gas insulated switchgear and the arrester thus taking full advantage of encapsulation.

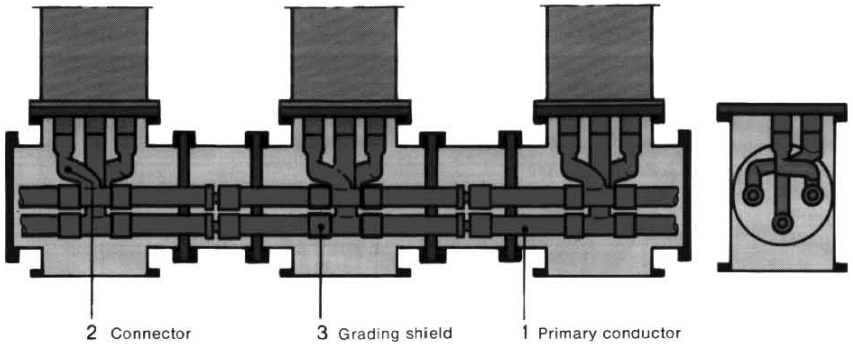
busbars - interconnections

Busbars and interconnections are made from cylindrical aluminium bars supported by the insulators with triangular bundled configuration.
Three short bars are sealed in each insulator and are used to fix the tubular bars.
These are fixed at one end by embedding which increases the rigidity of the system and improves its resistance to electrodynamic stresses, especially in the case of three-phase faults. At the other end, they are plugged into a connector loaded with contact fingers.
Steps are taken to ensure easy removal and replacement of busbars. When justified by their size, the busbars are subdivided into sealed compartments, each fitted with refilling and safety accessories, fitting devices, a pressure-switch, and overpressure limiter. Expansion bellows can be placed on the busbars and interconnecting elements for a variety of functions :
■ compensation for thermal expansion
■ compensation for misalignment and inaccuracies of civil works
■ vibration absorber
■ electrical insulation in the case of direct connection between the GIS and the power transformer.

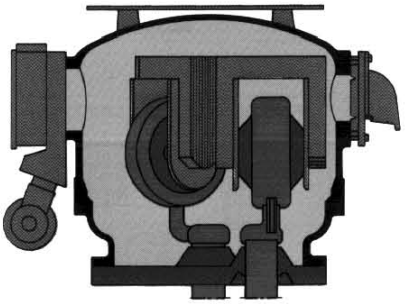
Electrical operating mechanism



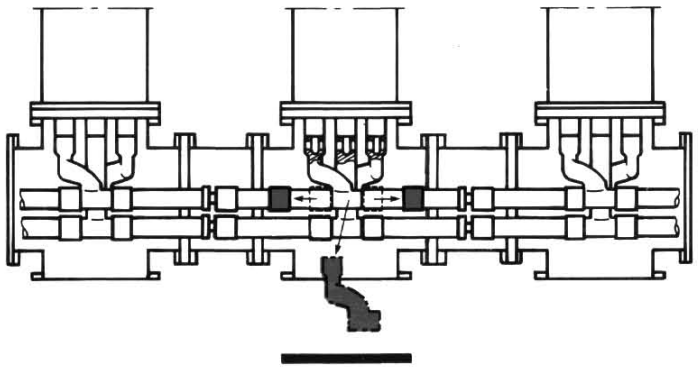
Busbars-Section



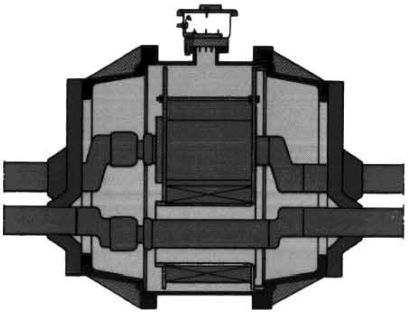
Voltage transformer - Section



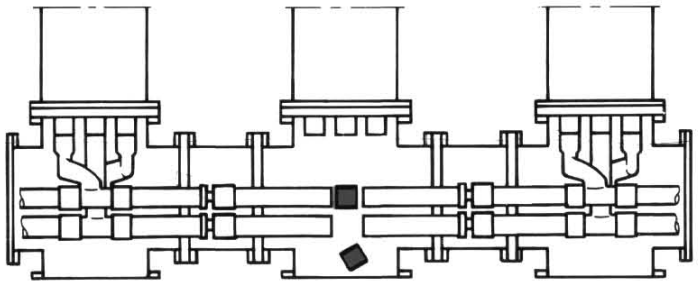
Busbar dismantling principle :



Current transformer - Section

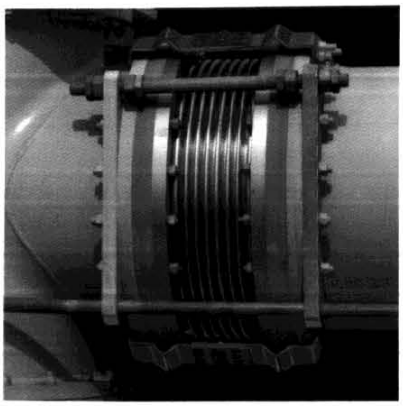


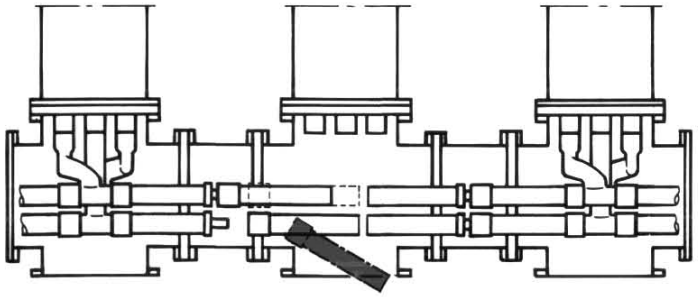
Moving of grading shields and dismantling of primary conductor supporting connectors



Removal of grading shields

Expansion bellow





Drawing out of primary conductor

Hexabloc TH7 electrical characteristics and functions

interfaces

These are the elements which enable the GIS to be connected either to the transmission lines or to the load side power transformers.

Air/SF6 bushing for overhead line connection
It comprises :
- an enclosure serving as the base and being an integral part of the gas insulated switchgear.
- three porcelain enclosures mounted on the base
each carrying its conductor
each connected to one of the three phases of the overhead line at its extremity.

The bushing is filled with SF6 and the enclosure is fitted with refilling and safety accessories.

Cable termination with GIS
Several types of cable end boxes are available according to the type of cable : dry or oil impregnated cable.
The cable termination of each phase is connected to the internal circuit of the GIS. The three cable terminations are placed in the same SF6 enclosure which is fitted with refilling and safety accessories.
On top of the box is an interconnection compartment, separated from the cable terminal by an insulator allowing connection with :
- the rest of the GIS in various directions
- the grounding switch
- the voltage transformer
- removable test links, for insulation measurement, dielectric tests or cable fault location.

Connection to power transformer
It can be single or three-phase depending on the type of transformer.
Between the intermediate enclosure and the GIS, there is generally an expansion bellow which serves to :
- electrically separate the transformer earthing from the substation earthing to avoid malfunctioning of transformer earthing protection
- give a certain mechanical flexibility :
  - □ making erection easier
  - □ preventing transformer vibrations from being transmitted to the substation
  - □ compensating misalignments.

Three-phase/single-phase interface
This interface allows single phase outputs or a three-phase extension of a single-phase substation. It can be used for connecting up certain types of air/SF6 bushings and transformers, or to meet particular specifications.

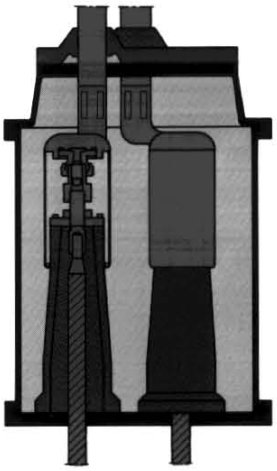
local control cubicle

There is generally one control cubicle per bay. It can be installed either near the bay or in a control and monitoring room with other similar equipment.

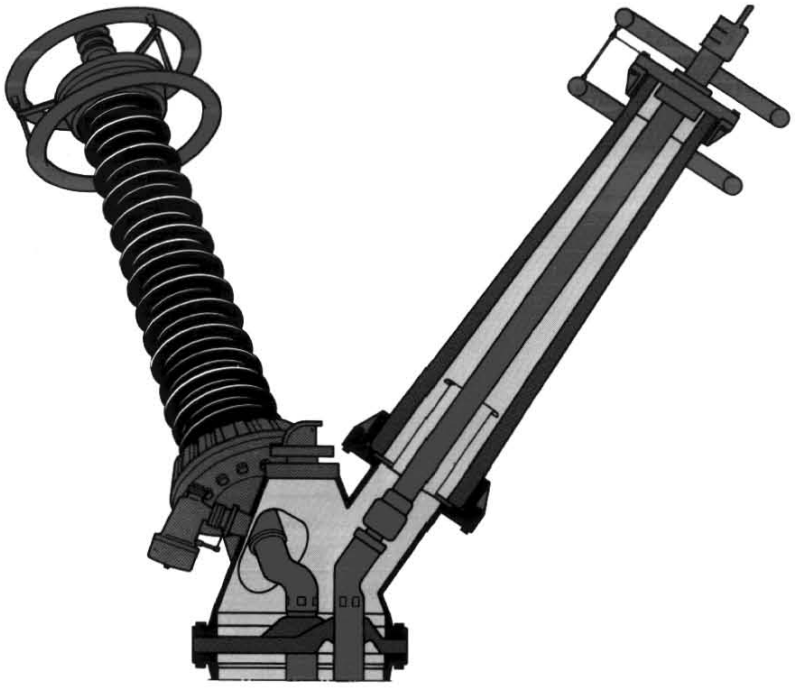
The cubicle holds all the equipment necessary for operating the gas insulated bay :
- control equipment : push button, signalling lamps, relays,...
- protection of GIS : pressure-switch indication, signalling and alarm sequences, electrical interlocks,...
- instrument transformer secondary connections.

The different functions of the bay are grouped together in corresponding «zones» (circuit-breakers, disconnectors, grounding switches, instrument transformers). This allows easy identification of equipment and quick intervention, whilst reducing the risk or errors.

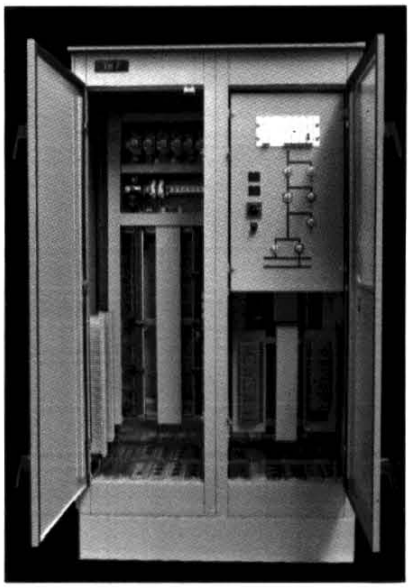
Cable termination - Section



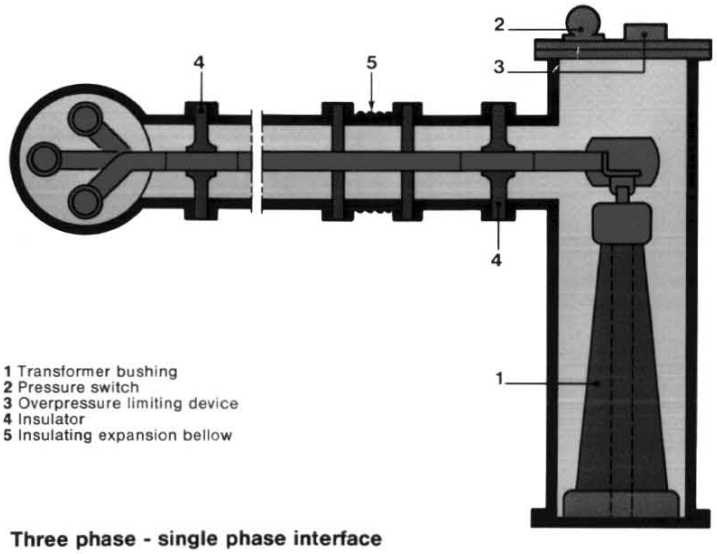
Air/SF6 bushing for overhead line connection



Control and signalling cubicle

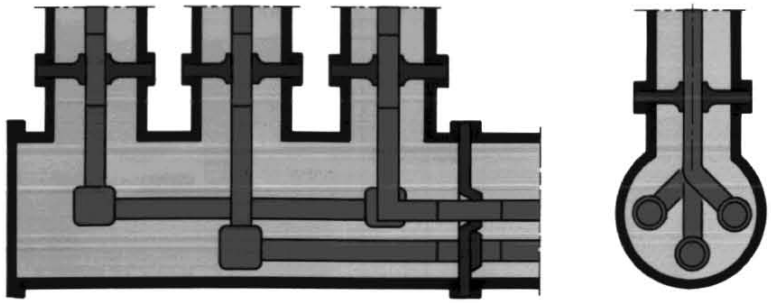


Connection to power transformer-Section



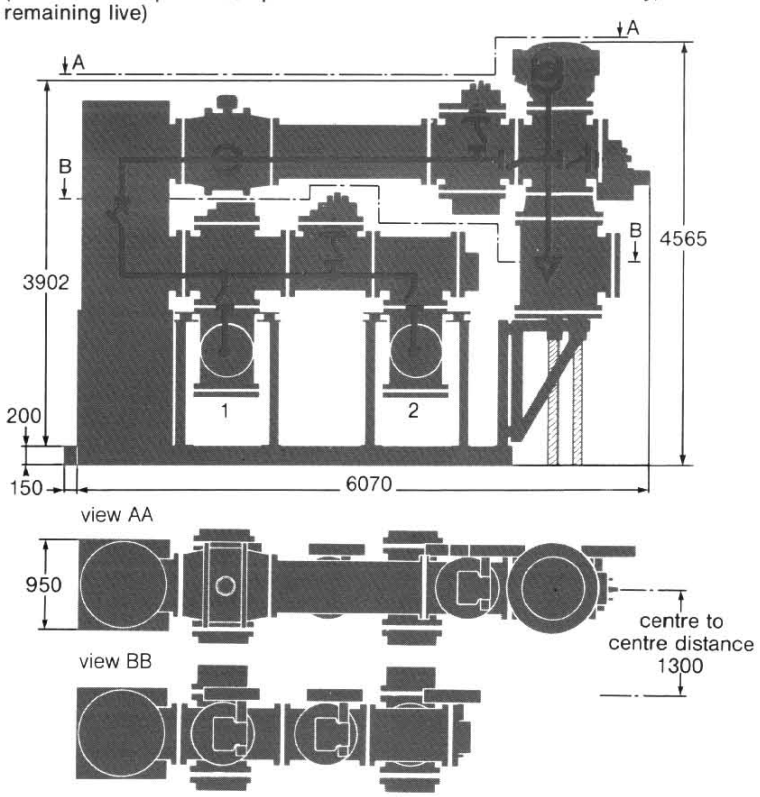
1 Transformer bushing
2 Pressure switch
3 Overpressure limiting device
4 Insulator
5 Insulating expansion bellow

Three phase - single phase interface

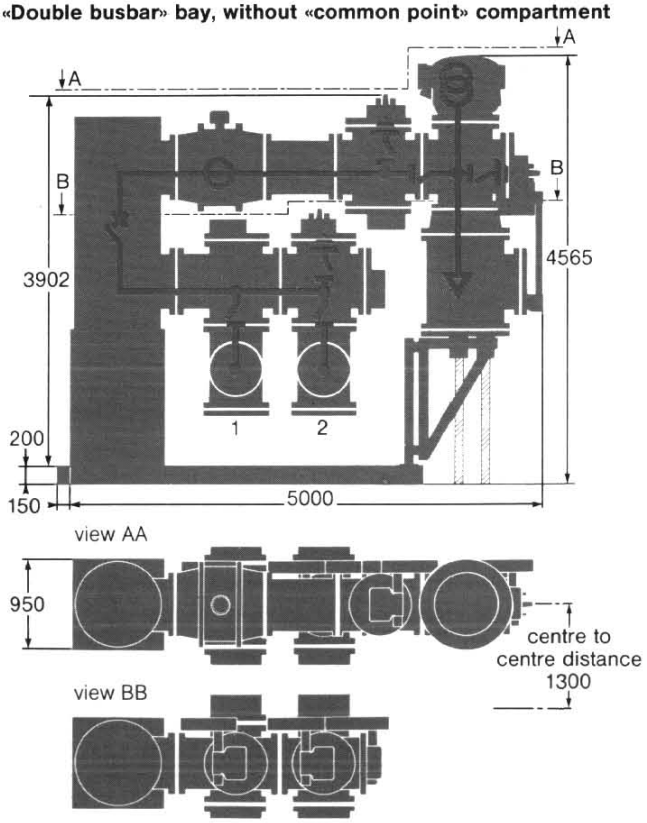


Hexabloc TH7 electrical characteristics and functions

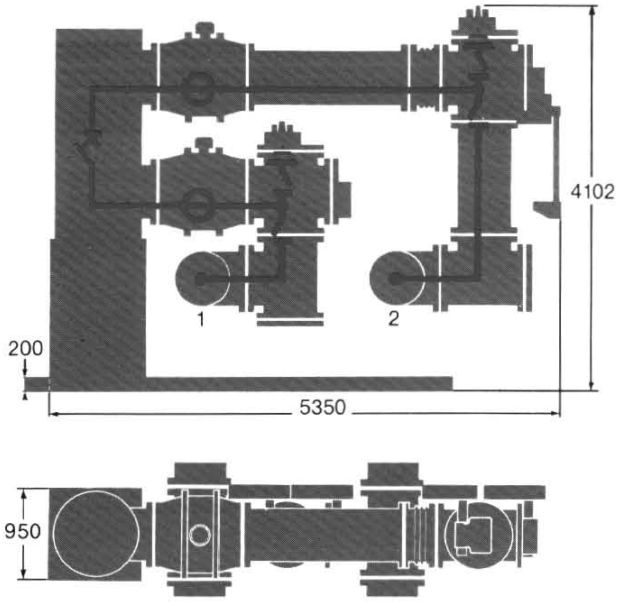
«Double busbar» bay, with «common point» compartment
(The «common point» compartment makes work easier on the bay, one of the busbars remaining live)



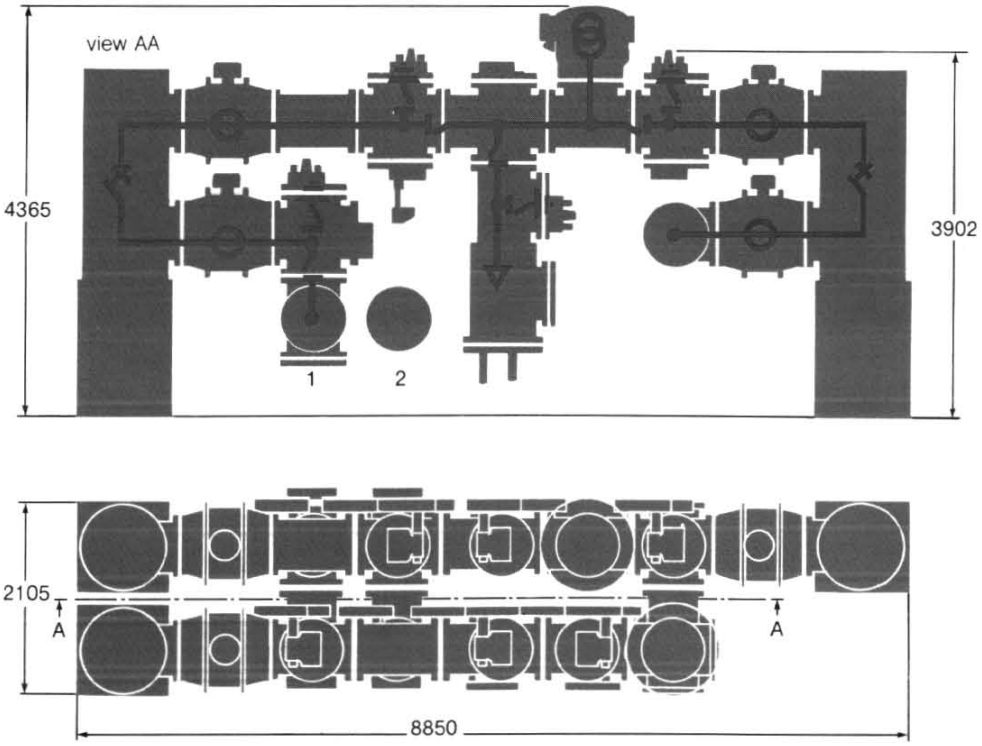
«Double busbar» bay, without «common point» compartment



Busbar coupling bay



«Breaker and a half» bay



transport installation

Merlin Gerin has succeeded in simplifying the erection on site by developing fully factory assembled bays. The amount of pre-assembly carried out depends on the mode of transportation used to carry the equipment to the site.
In most cases, a bay is transported to the site, fully factory assembled, purged, dried, and filled with reduced gas pressure, auxiliary circuits and the earth circuit completely wired up.

Erection on site is on very simple civil works, confining itself to :
- marking the position of the bays
- positioning and interconnection of factory assembled units
- topping up the gas to nominal pressure
- filling up of the units erected on site (busbar compartments, etc...)
- connecting auxiliary and earthing circuits
- pre-commissioning tests.

Precise quality control check lists and manuals ensure that all the equipment supplied has been correctly tested.

maintenance

One of the main advantages of Merlin Gerin's gas insulated switchgear is that it is practically maintenance free :
- The active parts, protected by encapsulation and the neutral SF6 gas require no maintenance during the whole life of the installation.
- Cleaning the insulators, a considerable constraint in open type substations, is practically eliminated.
- Very high electrical endurance of circuit-breaker contacts means that in most cases they will never be replaced.

Maintenance is thus virtually limited to monitoring :
- gas pressure and topping up if the pressure drops
- oil level in hydraulic operating mechanism of circuit-breaker and replacement of oil at regular intervals.

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